US009473764B2

(12) **United States Patent**
Hoffman et al.

(10) **Patent No.: US 9,473,764 B2**
(45) **Date of Patent: Oct. 18, 2016**

(54) **STEREOSCOPIC IMAGE DISPLAY**

(71) Applicant: **MICROSOFT TECHNOLOGY LICENSING, LLC**, Redmond, WA (US)

(72) Inventors: **Craig Lee Hoffman**, Sammamish, WA (US); **Richard Carl Roesler**, Bellevue, WA (US); **Travis William Steiner**, Issaquah, WA (US)

(73) Assignee: **MICROSOFT TECHNOLOGY LICENSING, LLC**, Redmond, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 98 days.

(21) Appl. No.: **14/318,451**

(22) Filed: **Jun. 27, 2014**

(65) **Prior Publication Data**

US 2015/0381974 A1 Dec. 31, 2015

(51) **Int. Cl.**

G06T 15/00	(2011.01)
H04N 13/04	(2006.01)
G02B 27/01	(2006.01)
H04N 13/00	(2006.01)
G06T 19/00	(2011.01)
H04N 13/02	(2006.01)

(52) **U.S. Cl.**

CPC ***H04N 13/0429*** (2013.01); ***G02B 27/017*** (2013.01); ***G02B 27/0179*** (2013.01); ***G06T 19/006*** (2013.01); ***H04N 13/0018*** (2013.01); ***H04N 13/0278*** (2013.01); ***H04N 13/044*** (2013.01); ***H04N 13/0409*** (2013.01); ***H04N 13/0484*** (2013.01); *G02B 2027/0178* (2013.01); *G02B 2027/0187* (2013.01); *H04N 13/0033* (2013.01); *H04N 2013/0096* (2013.01)

(58) **Field of Classification Search**

CPC G02B 27/017; G02B 2027/0178; G02B 2027/0127; G06F 3/012; G06F 3/011

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,929,189	B2	4/2011	Schwerdtner
8,395,616	B2	3/2013	Schwerdtner
2010/0149313	A1	6/2010	Kroll et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP	2458880 A2	5/2012
WO	2013145861 A1	10/2013

OTHER PUBLICATIONS

ISA European Patent Office, Invitation to Pay Additional Fees and, Where Applicable, Protest Fee Issued in Application No. PCT/US2015/037306, Sep. 14, 2015, WIPO, 6 pages.

(Continued)

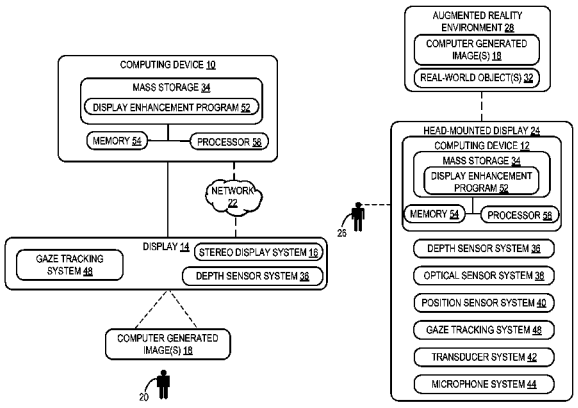
Primary Examiner — Peter Hoang

(74) *Attorney, Agent, or Firm* — Dan Choi; Micky Minhas

(57) **ABSTRACT**

Embodiments that relate to displaying a computer generated image to a viewer via a stereoscopic display system are disclosed. One disclosed embodiment comprises establishing a predetermined threshold distance from an eye of a viewer to a threshold displayed position of a computer generated image. The method includes determining that a vergence distance from the eye of the viewer to a current displayed position of the image is at or below the predetermined threshold distance. Based on the vergence distance being at or below the predetermined threshold distance, a size of the image is increased while maintaining the vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the image.

20 Claims, 9 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0149611	A1	6/2010	Leister
2011/0267338	A1	11/2011	Nam et al.
2013/0050258	A1	2/2013	Liu et al.
2013/0093848	A1	4/2013	Masuda
2013/0201446	A1	8/2013	Hall et al.
2013/0326364	A1	12/2013	Latta et al.
2015/0070477	A1	3/2015	Taki

OTHER PUBLICATIONS

ISA European Patent Office, International Search Report and Written Opinion Issued in Application No. PCT/US2015/037306, Nov. 20, 2015, WIPO, 19 pages.

Onural, et al., "Digital Holographic Three-Dimensional Video Displays", In Proceedings of the IEEE, vol. 99 , Issue 4, Apr. 2011, 14 pages.

Kozacki, Tomasz, "On Resolution and Viewing of Holographic Image Generated by 3D Holographic Display", In Proceedings of the Optics Express, vol. 18, Issue 26, Dec. 9, 2010, 12 pages.

Halle, et al., "The Ultragram: A Generalized Holographic Stereogram", In Proceedings of the SPIE Practical Holography V, Feb. 1991, 13 pages.

Nishchal, et al., "Reconstruction of Fresnel Digital Hologram Using Fractional Fourier Transform Algorithm", Published on: Dec. 6, 2013, Available at: http://www.digitalholography.eu/varasto/Nishchal_Naughton_Photonics_2010.pdf.

IPEA European Patent Office, Second Written Opinion issued in Application No. PCT/US2015/037306, Mar. 30, 2016, WIPO, 8 pages.

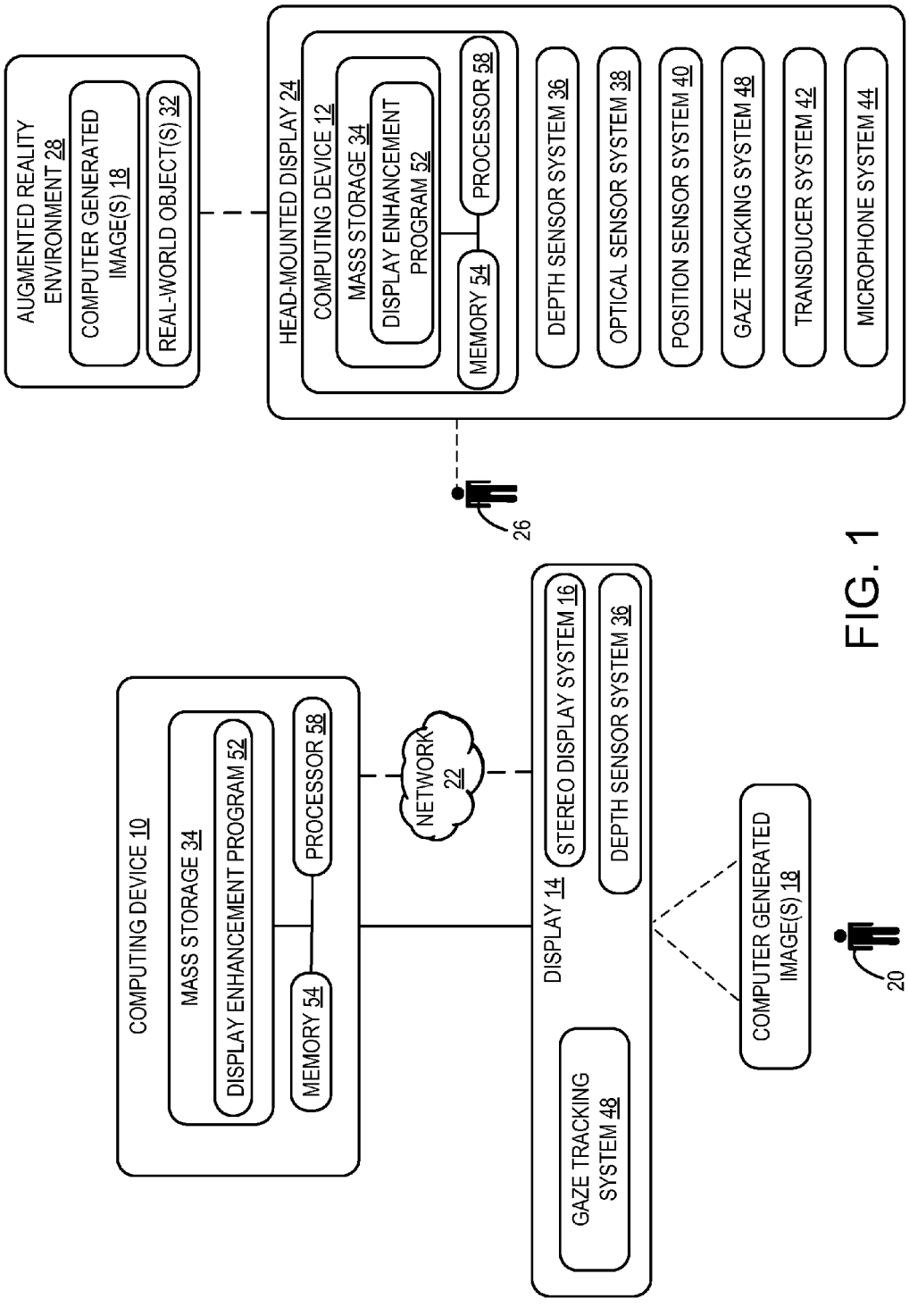

AUGMENTED REALITY ENVIRONMENT 28
COMPUTER GENERATED IMAGE(S) 18
REAL-WORLD OBJECT(S) 32
HEAD-MOUNTED DISPLAY 24
COMPUTING DEVICE 12
MASS STORAGE 34
DISPLAY ENHANCEMENT PROGRAM 52
MEMORY 54
PROCESSOR 58
DEPTH SENSOR SYSTEM 36
OPTICAL SENSOR SYSTEM 38
POSITION SENSOR SYSTEM 40
GAZE TRACKING SYSTEM 48
TRANSDUCER SYSTEM 42
MICROPHONE SYSTEM 44
26
COMPUTING DEVICE 10
MASS STORAGE 34
DISPLAY ENHANCEMENT PROGRAM 52
MEMORY 54
PROCESSOR 58
NETWORK 22
DISPLAY 14
STEREO DISPLAY SYSTEM 16
DEPTH SENSOR SYSTEM 36
GAZE TRACKING SYSTEM 48
COMPUTER GENERATED IMAGE(S) 18
20

FIG. 1

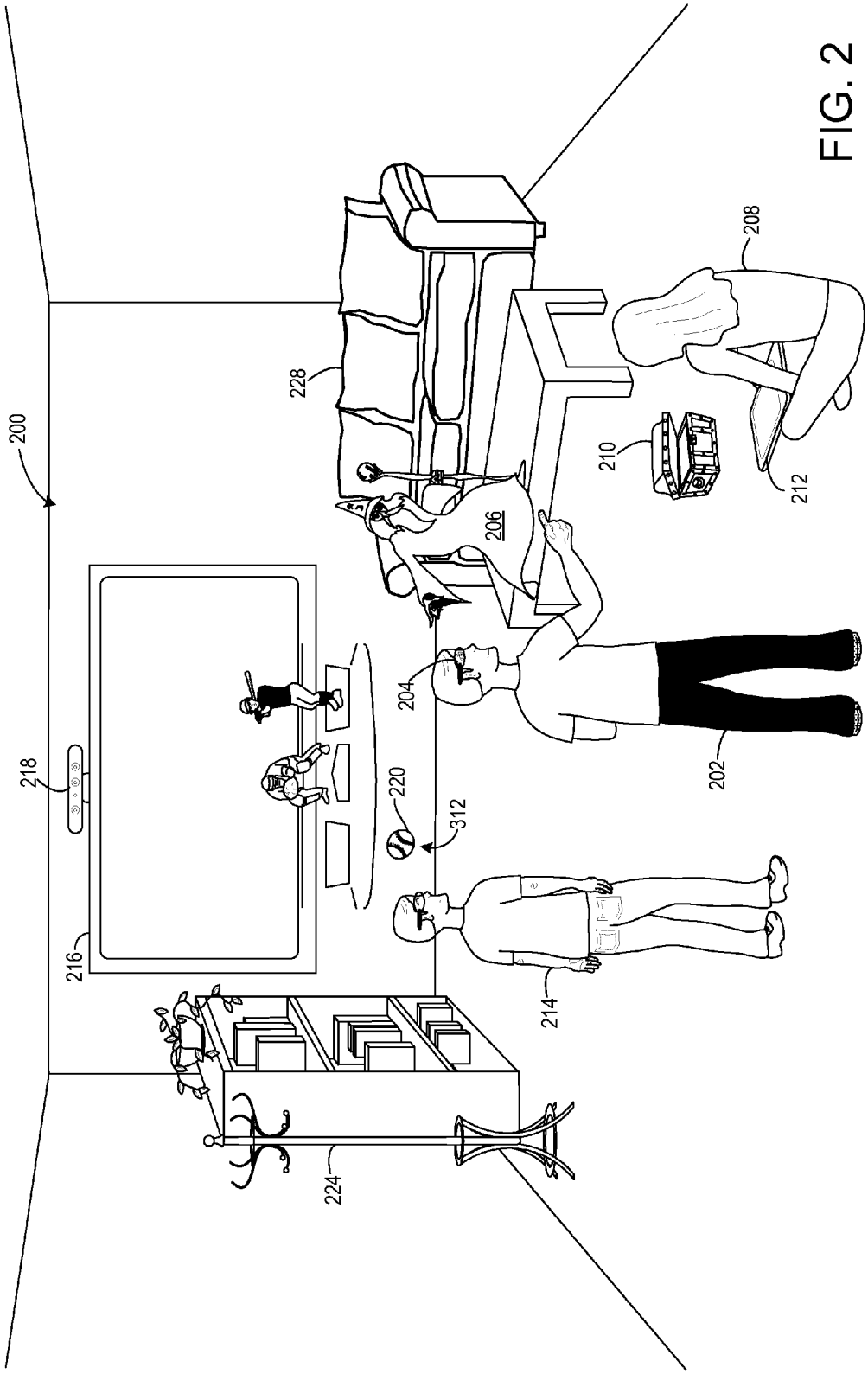


FIG. 2

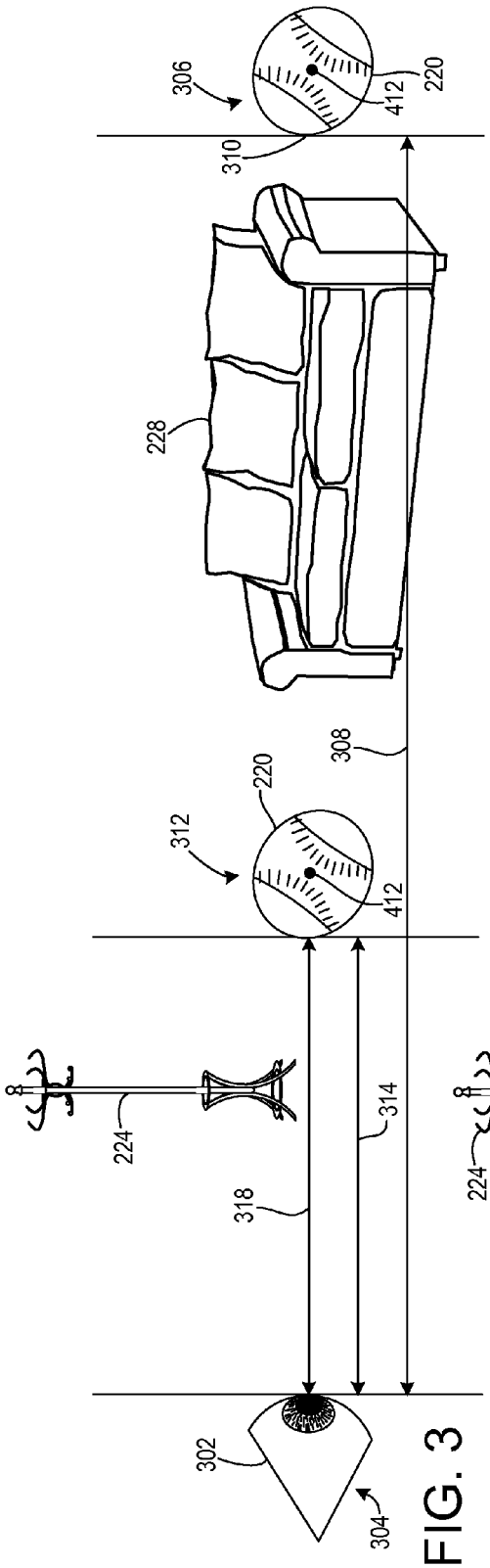

306
310
220
412
228
308
312
220
412
224
314
318
302
304

FIG. 3

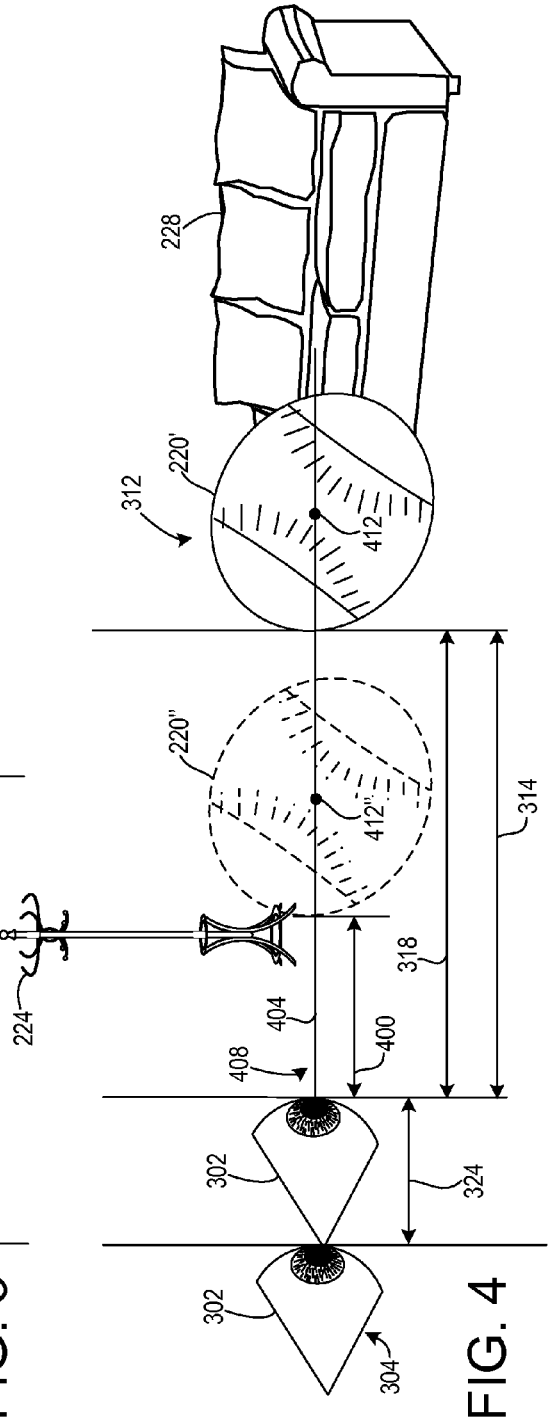

228
312
220'
412
220"
412"
314
224
318
404
400
408
302
324
304

FIG. 4

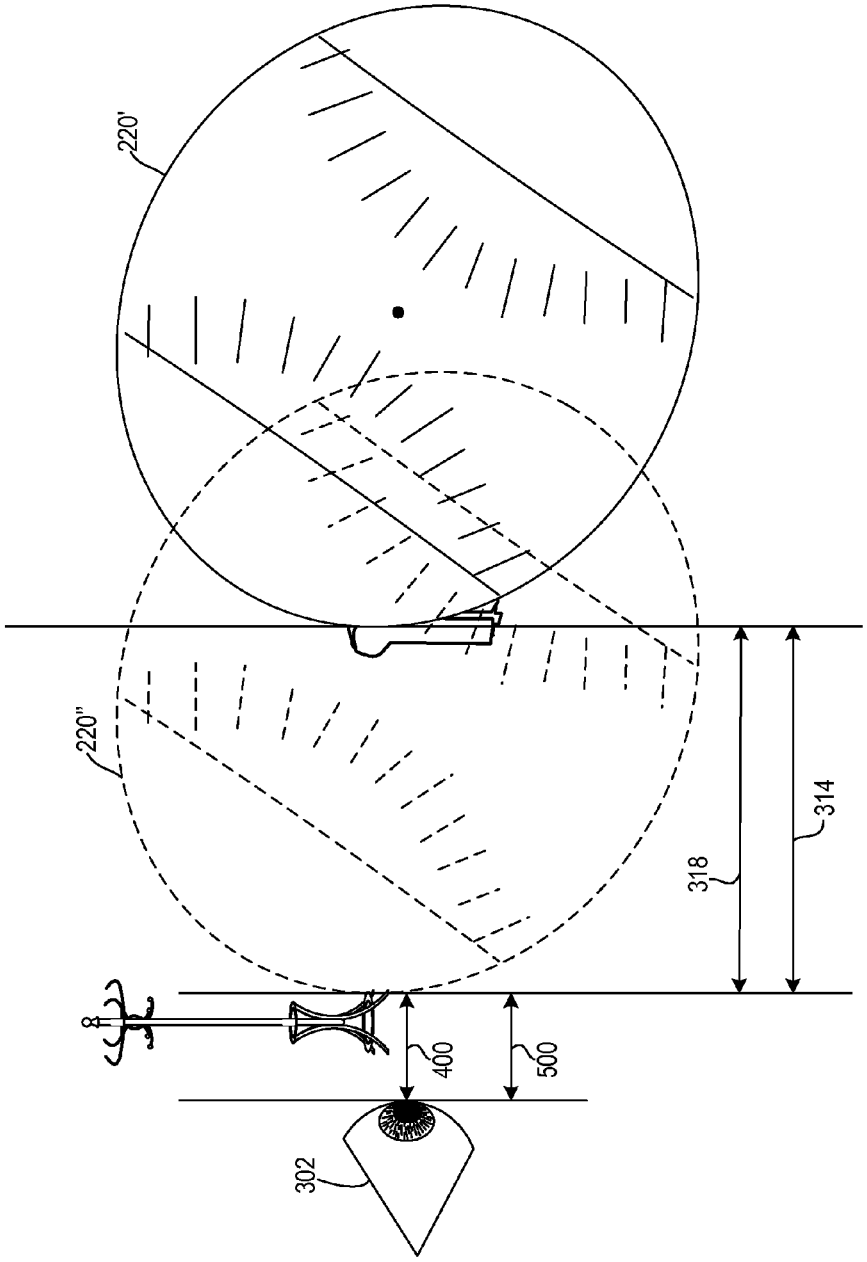


FIG. 5

FIG. 6

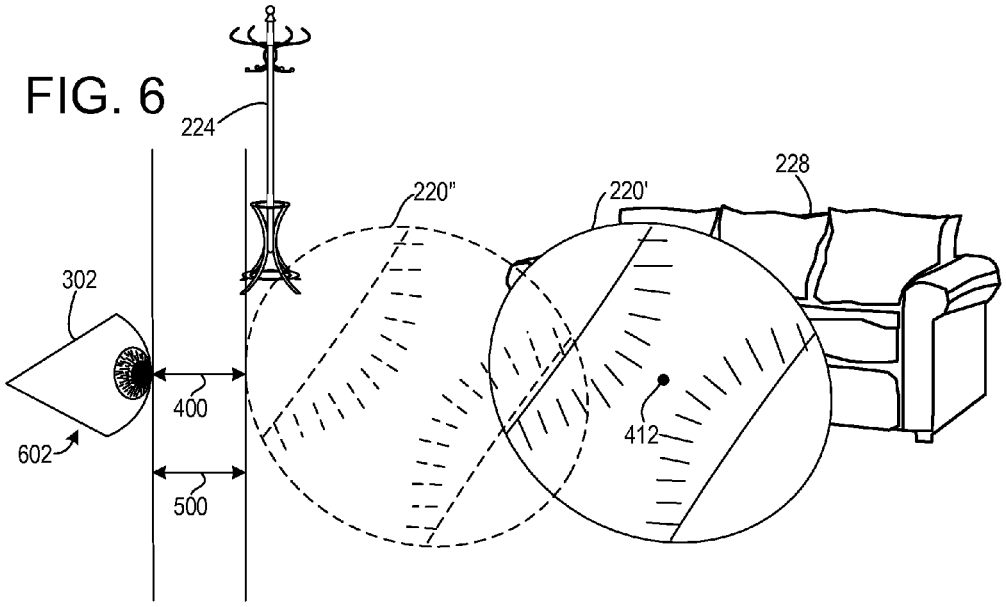
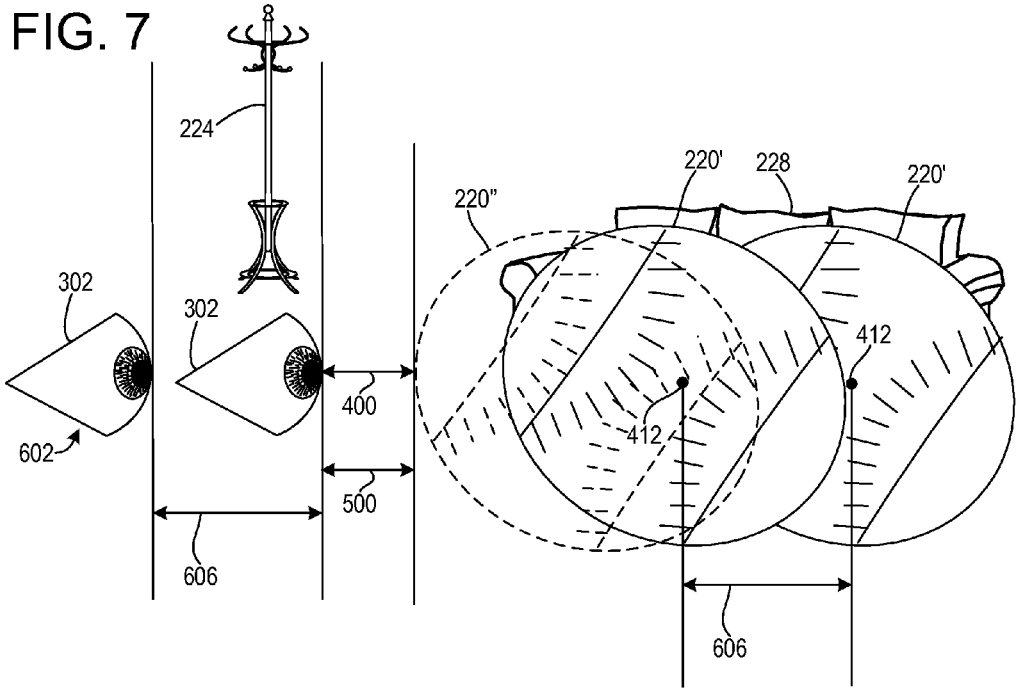

224
220"
220'
228
302
400
602
500
412

FIG. 7


224
220'
228
220'
220"
302
302
412
400
412
602
500
606
606

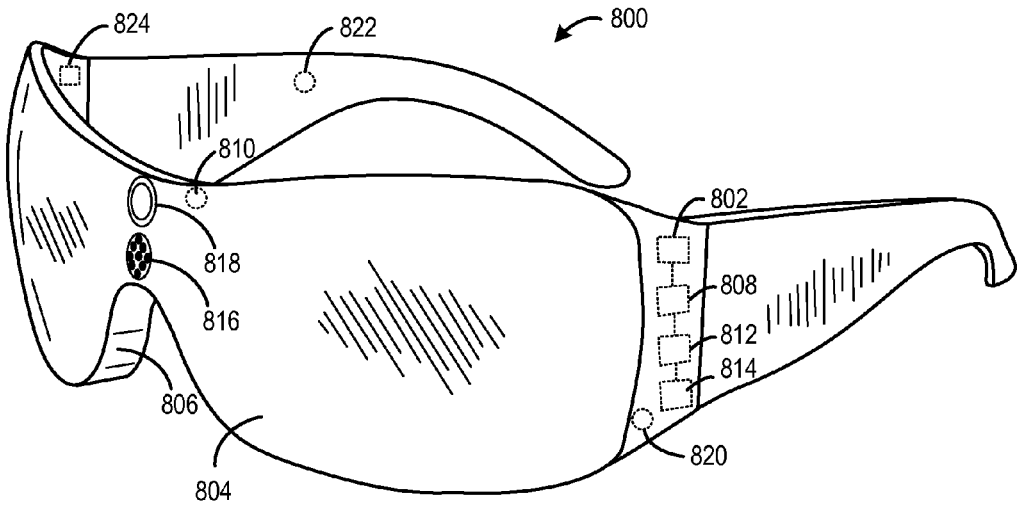


FIG. 8

FIG. 9A

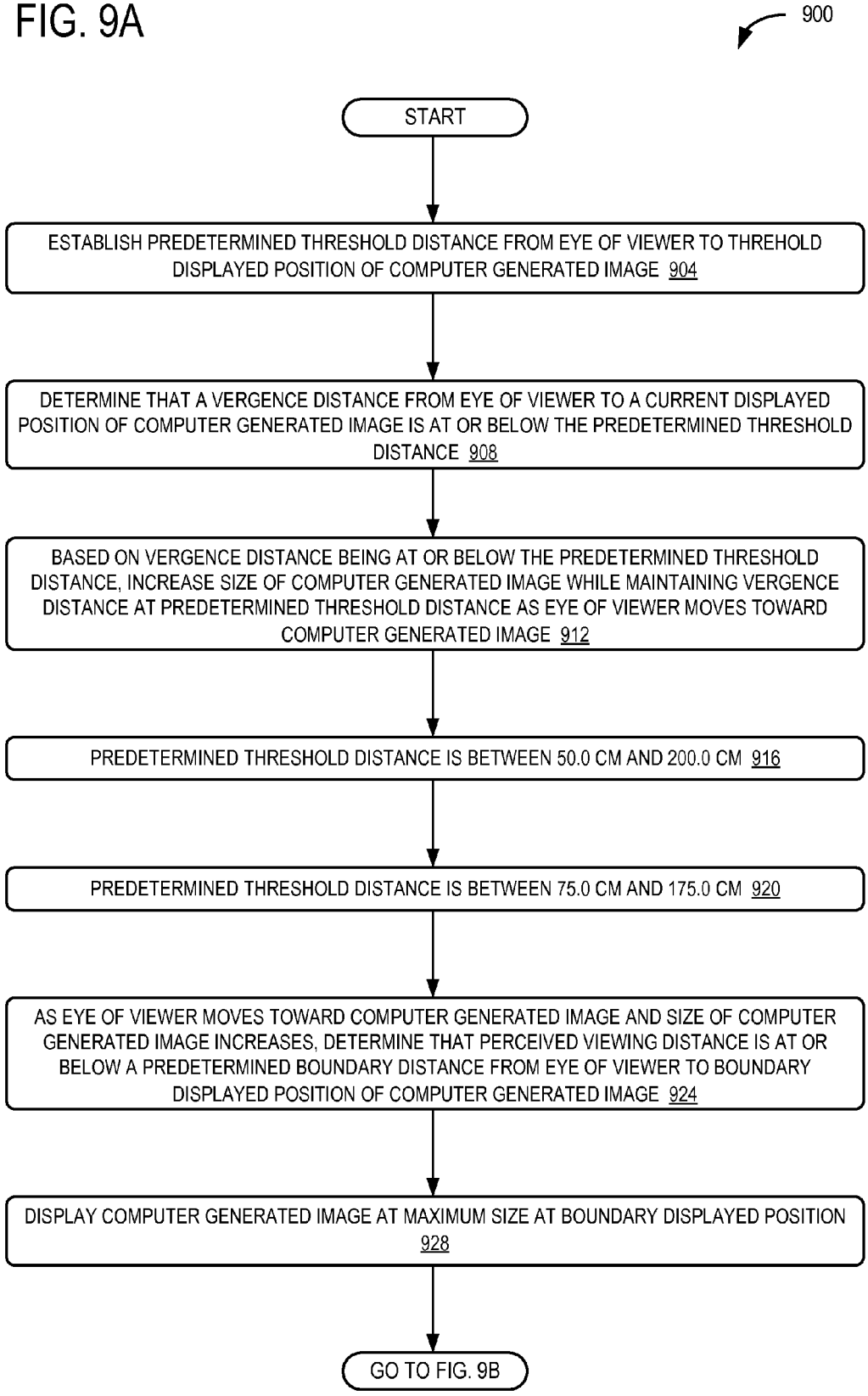
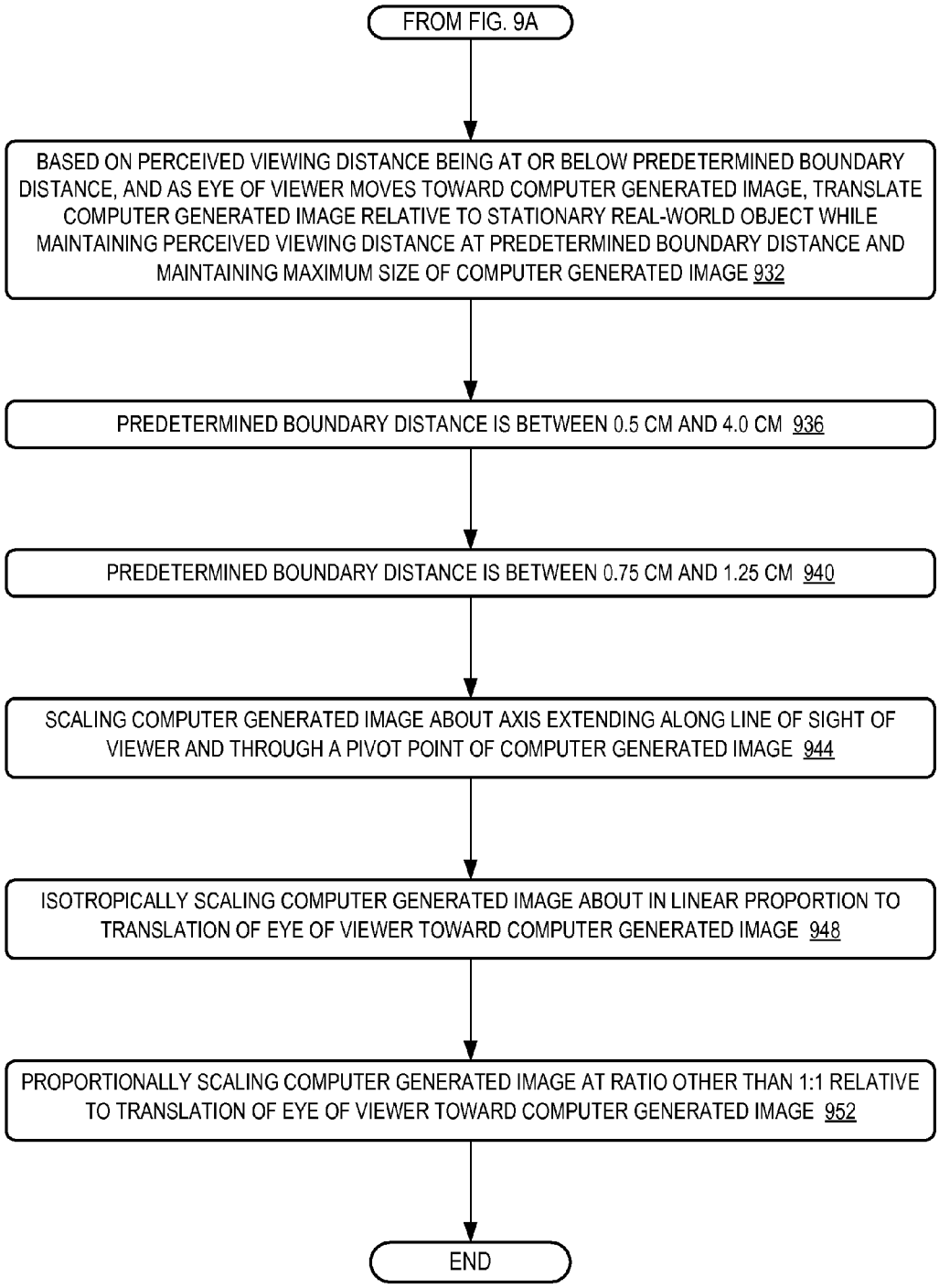

900
START
ESTABLISH PREDETERMINED THRESHOLD DISTANCE FROM EYE OF VIEWER TO THREHOLD DISPLAYED POSITION OF COMPUTER GENERATED IMAGE 904
DETERMINE THAT A VERGENCE DISTANCE FROM EYE OF VIEWER TO A CURRENT DISPLAYED POSITION OF COMPUTER GENERATED IMAGE IS AT OR BELOW THE PREDETERMINED THRESHOLD DISTANCE 908
BASED ON VERGENCE DISTANCE BEING AT OR BELOW THE PREDETERMINED THRESHOLD DISTANCE, INCREASE SIZE OF COMPUTER GENERATED IMAGE WHILE MAINTAINING VERGENCE DISTANCE AT PREDETERMINED THRESHOLD DISTANCE AS EYE OF VIEWER MOVES TOWARD COMPUTER GENERATED IMAGE 912
PREDETERMINED THRESHOLD DISTANCE IS BETWEEN 50.0 CM AND 200.0 CM 916
PREDETERMINED THRESHOLD DISTANCE IS BETWEEN 75.0 CM AND 175.0 CM 920
AS EYE OF VIEWER MOVES TOWARD COMPUTER GENERATED IMAGE AND SIZE OF COMPUTER GENERATED IMAGE INCREASES, DETERMINE THAT PERCEIVED VIEWING DISTANCE IS AT OR BELOW A PREDETERMINED BOUNDARY DISTANCE FROM EYE OF VIEWER TO BOUNDARY DISPLAYED POSITION OF COMPUTER GENERATED IMAGE 924
DISPLAY COMPUTER GENERATED IMAGE AT MAXIMUM SIZE AT BOUNDARY DISPLAYED POSITION 928
GO TO FIG. 9B

FIG. 9B


FROM FIG. 9A
BASED ON PERCEIVED VIEWING DISTANCE BEING AT OR BELOW PREDETERMINED BOUNDARY DISTANCE, AND AS EYE OF VIEWER MOVES TOWARD COMPUTER GENERATED IMAGE, TRANSLATE COMPUTER GENERATED IMAGE RELATIVE TO STATIONARY REAL-WORLD OBJECT WHILE MAINTAINING PERCEIVED VIEWING DISTANCE AT PREDETERMINED BOUNDARY DISTANCE AND MAINTAINING MAXIMUM SIZE OF COMPUTER GENERATED IMAGE 932
PREDETERMINED BOUNDARY DISTANCE IS BETWEEN 0.5 CM AND 4.0 CM 936
PREDETERMINED BOUNDARY DISTANCE IS BETWEEN 0.75 CM AND 1.25 CM 940
SCALING COMPUTER GENERATED IMAGE ABOUT AXIS EXTENDING ALONG LINE OF SIGHT OF VIEWER AND THROUGH A PIVOT POINT OF COMPUTER GENERATED IMAGE 944
ISOTROPICALLY SCALING COMPUTER GENERATED IMAGE ABOUT IN LINEAR PROPORTION TO TRANSLATION OF EYE OF VIEWER TOWARD COMPUTER GENERATED IMAGE 948
PROPORTIONALLY SCALING COMPUTER GENERATED IMAGE AT RATIO OTHER THAN 1:1 RELATIVE TO TRANSLATION OF EYE OF VIEWER TOWARD COMPUTER GENERATED IMAGE 952
END

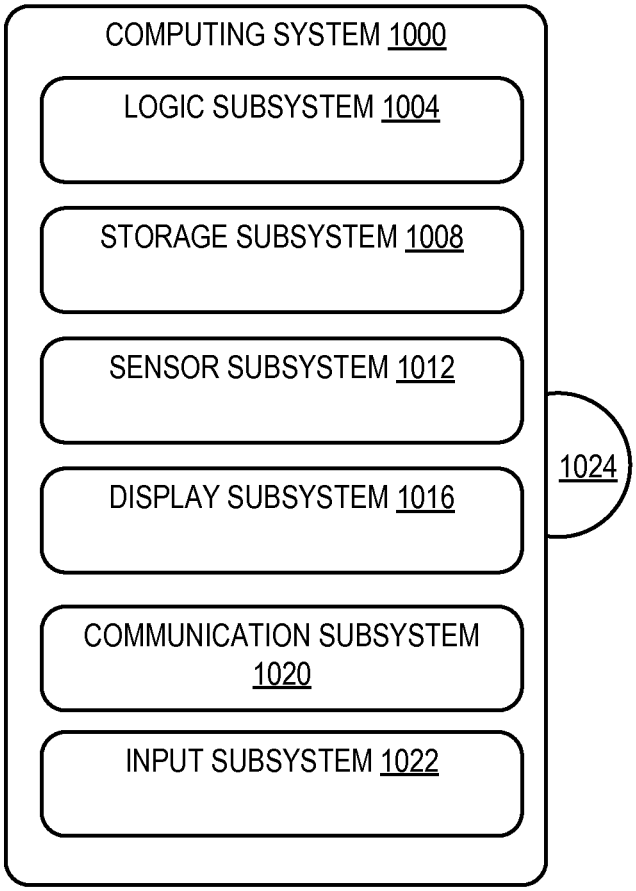

COMPUTING SYSTEM 1000
LOGIC SUBSYSTEM 1004
STORAGE SUBSYSTEM 1008
SENSOR SUBSYSTEM 1012
DISPLAY SUBSYSTEM 1016
1024
COMMUNICATION SUBSYSTEM 1020
INPUT SUBSYSTEM 1022

FIG. 10

STEREOSCOPIC IMAGE DISPLAY

BACKGROUND

Various display technologies may display computer generated images, such as three-dimensional holograms or two-dimensional images, to create an immersive virtual reality or augmented reality viewing experience. For example, some stereoscopic display devices, such as head-mounted display (HMD) devices, may comprise a see-through display that allows superposition of images over a real-world environment. The images may appear integrated with the real-world environment when viewed through the see-through display of the HMD device. Such a relationship between virtual images and the real-world environment may be referred to as augmented reality.

Where an image is generated by a stereoscopic display, light comprising the image originates at a display screen or other surface and travels to the eyes of the viewer over an actual viewing distance. In some examples, the light may be controlled to create a viewer-perceived location of the image at a distance from the viewer that is different from the actual viewing distance of the display screen or surface. For example, an HMD device displays images that are perceived by the viewer to be at distance from the viewer's eyes that is greater than the eye relief distance between eyes and the HMD screen or lens.

In some examples, a viewer may approach a computer generated image to appreciate image details or otherwise interact with the image. In other examples an image may be displayed to move closer to the viewer. It has been discovered, however, that as the distance between the viewer and a perceived location of the image decreases, at certain distances some viewers may experience discomfort such as dizziness, headaches, double vision and/or other issues. Because of these viewer comfort issues, some display devices may impose a minimum viewing distance that limits the perceived proximity of a displayed image. Unfortunately, such minimum viewing distances may prevent viewers from more closely approaching an image, and may thereby limit interactive experiences and related features of augmented or virtual reality applications. Additionally, such minimum viewing distances negatively impact the viewing experiences of viewers who are not affected by viewing comfort issues.

SUMMARY

Various embodiments are disclosed herein that relate to displaying a computer generated image to a viewer via a stereoscopic display system. For example, one disclosed embodiment provides a method comprising establishing a predetermined threshold distance from an eye of the viewer to a threshold displayed position of the computer generated image. The method includes determining that a vergence distance from the eye of the viewer to a current displayed position of the computer generated image is at or below the predetermined threshold distance. Based on the vergence distance being at or below the predetermined threshold distance, a size of the computer generated image is increased while maintaining the vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the computer generated image.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of example display devices that may display computer generated images via stereoscopic display systems according to examples of the present disclosure.

FIG. **2** is a schematic view of viewers in a room interacting with display devices that may display computer generated images via a stereoscopic display system according to examples of the present disclosure.

FIG. **3** schematically shows a computer generated image at two viewer-perceived distances from an eye of a viewer.

FIG. **4** schematically shows a computer generated image of FIG. **3** increased in size as the eye of the viewer moves toward the image.

FIG. **5** schematically shows the computer generated image of FIG. **4** displayed at a maximum size when the perceived viewing distance is at a predetermined boundary distance.

FIGS. **6** and **7** schematically show the computer generated image of FIG. **5** translated relative to stationary real-world objects as the viewer's eye moves toward the image.

FIG. **8** schematically shows an example head-mounted display device according to an embodiment of the present disclosure.

FIGS. **9**A and **9**B are a flow chart of a method for displaying a computer generated image to a viewer via a stereoscopic display system according to an embodiment of the present disclosure.

FIG. **10** is a simplified schematic illustration of an embodiment of a computing device.

DETAILED DESCRIPTION

FIG. **1** shows a schematic view of example implementations of computing devices and associated stereoscopic display devices that may be utilized to display computer generated images to a viewer. As described in more detail below, in one example a display enhancement program executed by a processor of a computing device may establish a predetermined threshold distance from an eye of the viewer to a threshold displayed position of a computer generated image. The program may determine that a vergence distance from the eye of the viewer to a current displayed position of the computer generated image is at or below the predetermined threshold distance. Based on the vergence distance being at or below the predetermined threshold distance, and as the eye of the viewer moves toward the computer generated image, the size of the computer generated image may be increased while maintaining the vergence distance at the predetermined threshold distance.

In various examples, the computing devices may be either physically separated from or integrated into a display device with which a viewer may interact. FIG. **1** schematically shows an example of a computing device **10** that is physically separated from a stereoscopic display device **14**. The display device **14** may include a stereoscopic display system **16** for presenting one or more computer generated images **18** to a first viewer **20**. In this example, the computing device **10** may comprise or be integrated into a separate device,

such as a set-top box, gaming console, web camera, head-mounted computing device or other wearable computing device, keyboard, dedicated peripheral, or other like device that does not include an integrated display.

The computing device **10** may be operatively connected with the display device **14** using a wired connection, or may employ a wireless connection via WiFi, Bluetooth, or any other suitable wireless communication protocol. For example, the computing device **10** may be communicatively coupled to a network **22**. The network **22** may take the form of a local area network (LAN), wide area network (WAN), wired network, wireless network, personal area network, or a combination thereof, and may include the Internet. Additional details regarding the components and computing aspects of the computing device **10** are described in more detail below with reference to FIG. **10**.

FIG. **1** also shows an example of a computing device **12** that is integrated into a head-mounted display (HMD) device **24**. The HMD device **24** may comprise a transparent, semi-transparent or non-transparent display that is supported in front of a viewer's eye or eyes. In some examples, the HMD device **24** may create and display to a second viewer **26** an augmented reality environment **28** that includes one or more computer generated images **18** that are displayed among one or more real-world objects **32** in a physical environment viewed through the device. The computer generated images **18** may comprise three-dimensional (3D) holographic images, two-dimensional (2D) images, or other forms of virtual images that are generated and displayed via HMD device **24**. The HMD device **24** may thereby enable the second viewer **26** to view such computer generated images **18** within the physical environment surrounding the viewer.

As described in more detail below, the HMD device **24** may include various sensors and related systems that receive physical environment data from the physical environment. For example, the HMD device **24** may include a depth sensor system **36** that includes one or more depth cameras that generate depth image data from real-world objects **32** in the surrounding physical environment. In some examples the HMD device **24** may include an optical sensor system **38** that utilizes at least one outward facing sensor, such as an RGB camera or other optical sensor. The outward facing sensor may capture two-dimensional image information from real-world objects **32** in the physical environment. The HMD device **24** may also include a position sensor system **40** comprising one or more accelerometers, gyroscopes, head tracking systems, and/or other sensors for determining a position or orientation of a user.

In some examples the HMD device **24** may include a transducer system **42** comprising one or more actuators that convert an electrical signal into another form of energy. The transducer system **42** may include one or more speakers for providing audio feedback to a viewer. In other examples the transducer system **42** may include one or more tactile transducers for generating and providing haptic feedback to the viewer, such as vibrations. The HMD device **24** may also include a microphone system **44** and one or more microphones for receiving audio input from the physical environment.

The example HMD device **24** illustrated in FIG. **1** shows the computing device **12** integrated into the HMD device. It will be appreciated that in other examples the computing device **12** may be a separate component from the HMD device **24**. Many types and configurations of HMD devices **24** having various form factors also may be used and are within the scope of the present disclosure. A more detailed description of an example HMD device is provided below with reference to FIG. **8**.

It also will be appreciated that the computing device **12** may comprise or be integrated into any other suitable type or form of display device or other computing device, such as a tablet, notebook, smartphone, or other mobile computing device, desktop computing device, standalone monitor, wall-mounted display, interactive whiteboard, or other like device having an integrated stereoscopic display.

Computing device **10** and computing device **12** also may receive gaze tracking data from a gaze tracking system **48**. In various examples the gaze tracking system **48** may be located in display device **14**, HMD device **24**, or in a common enclosure with any other suitable type or form of display device, including but not limited to those example devices having an integrated display discussed above. In other examples, a gaze tracking system **48**, depth sensor system **36** and computing device may be integrated into a common enclosure that does not include an integrated display, such as a head-mounted or other wearable device, or in any other suitable type or form of computing device that does not include an integrated display, including but not limited to those example devices without an integrated display discussed above. More detailed descriptions of example gaze tracking systems **48** are discussed below with reference to example HMD device **800** illustrated in FIG. **8**.

Both computing device **10** and computing device **12** may include a display enhancement program **52** that may be stored in mass storage **34**. The display enhancement program **52** may be loaded into memory **54** and executed by a processor **58** to perform one or more of the methods and processes described in more detail below.

In some examples, the display enhancement program **52** may utilize at least two different display modes for displaying the computer generated images **18**. More particularly, in a world-lock display mode one or more computer generated images **18** may be displayed via the display device **14** or HMD device **24** with world-locked positions. In a world-locked position, a computer generated image **18** appears to be fixed relative to real-world objects **32** viewable via the display device **14** or HMD device **24**. Correspondingly, in this mode the world-locked position of each computer generated image **18** appears to be moveable relative to a wearer of the HMD device **24**.

In some examples of HMD device **24**, a world-lock display mode may be associated with a six degree of freedom (6DOF) tracking system that estimates a location and an orientation of the HMD device **24** in six degrees of freedom (e.g., x, y, z, pitch, roll, yaw). For example, the estimate in six degrees of freedom may be determined using sensor data from optical sensor system **38**, position sensor system **40**, and or other sensors of the HMD device **24**.

In other examples, the HMD device **24** and/or display device **14** may operate in a body-lock display mode in which one or more computer generated images **18** may be displayed with body-locked positions. In a body-locked position, a computer generated image **18** appears to be fixed relative to the viewer, and the body-locked position of each computer generated image appears to be moveable relative to the real-world objects **32**.

In some examples of HMD device **24**, a body-lock display mode may be associated with a three degree of freedom (3DOF) tracking system that may operate in parallel with a 6DOF tracking system. The 3DOF tracking system may estimate an orientation of the HMD device **24** in three degrees of freedom (e.g., pitch, roll, yaw). For example, the

estimate in three degrees of freedom may be determined using data from the position sensor system **40**.

With reference now to FIGS. **2-7**, example use cases of display device **14** and HMD device **24** will now be described. FIG. **2** is a schematic illustration of several viewers in a room **200** interacting with computing devices and associated stereoscopic display devices that display computer generated images via a display enhancement program **52**. In one example, viewer Galen **202** is wearing an HMD device **204** that is generating an augmented reality movie including a 3D holographic wizard **206**. In another example, viewer Kara **208** is playing a treasure hunt game that includes a 3D holographic treasure chest **210** displayed by her laptop **212**.

In another example, viewer Meb **214** is playing a 3D interactive baseball game that is displayed by a wall-mounted display **216**. In some examples viewer Meb **214** may wear glasses that assist in creating an augmented reality experience by, for example, fusing two images into a single 3D image that is perceived by Meb to float in space.

In this example, wall-mounted display **216** is communicatively coupled to a set-top box **218** that comprises a depth sensor system **36**, a gaze tracking system **48** and a computing device that includes display enhancement program **52**. Using data from the depth sensor system **36** the set-top box **218** may monitor the position of viewer Meb **214** within room **200**. Using gaze tracking data from the gaze tracking system **48**, the set-top box **218** may also monitor viewer Meb's gaze location with respect to real-world objects within the room **200** and 3D images generated by the baseball game and displayed via the wall-mounted display **216**.

In one example, a 3D spherical computer generated baseball image **220** may be displayed in a world-lock display mode as floating stationary in space between viewer Meb **214** and computer generated images of a batter, catcher and home plate. In this manner, as viewer Meb **214** changes his position in the room **200**, Meb perceives the baseball image **220** as remaining stationary with respect to the wall-mounted display **216**, coat rack **224**, couch **228** and other real-world objects in room **200**.

With reference now to FIGS. **3** and **4**, an eye **302** of viewer Meb **214** is schematically illustrated in relation to the coat rack **224** and couch **228** in room **200**. As shown in FIG. **3** and with the eye **302** at an initial location **304**, a first current displayed position **306** of the baseball image **220** as perceived by viewer Meb **214** may be across the room at a first, relatively large vergence distance **308** from eye **302**. In the present example, the first vergence distance **308** may be further defined as the distance between the eye **302** and a point **310** at which the eye is gazing on the baseball image **220** in the first current displayed position **306**. In other examples, a vergence distance may be defined as the distance between the eye of a viewer and a predetermined location associated with the image, such as a leading edge of the image closest to the eye, a center of the image, or any other suitable location associated with the image.

With reference also to FIG. **2**, the baseball image **220** may be displayed at a second current displayed position **312** as perceived by viewer Meb **214** that is located at a second vergence distance **314** that is closer to his eye **302**. As noted above and to avoid potential viewer discomfort issues, the display enhancement program **52** may establish a predetermined threshold distance **318** from viewer Meb's eye **302** to a threshold displayed position of the baseball image **220**. In the present example and as shown in FIG. **3**, the second current displayed position **312** of baseball image **220** is located at the predetermined threshold distance **318** from eye **302**. Accordingly, the second current displayed position **312** corresponds to the threshold displayed position.

When the baseball image **220** is displayed at the second current displayed position **312**, the display enhancement program **52** may determine that the second vergence distance **314** is at the predetermined threshold distance **318**. It will also be appreciated that in some examples, due to processing limitations, data sampling intervals, and/or other constraints, the display enhancement program **52** may determine that the second vergence distance **314** is below the predetermined threshold distance **318**. For example, where viewer Meb **214** is moving toward the baseball image **220**, the display enhancement program **52** may not determine the second vergence distance **314** until the distance is slightly below the predetermined threshold distance **318**. In these examples, the display enhancement program may then adjust the second vergence distance **314** to match the predetermined threshold distance **318**.

Returning to the example of FIG. **3**, and with the baseball image **220** at the second current displayed position **312**, viewer Meb **214** may desire to obtain a closer view of the image. Accordingly and with reference now also to FIG. **4**, viewer Meb **214** may move toward the baseball image by a translation distance **324**. Because the second vergence distance **314** is at the predetermined threshold distance **318**, and in one potential advantage of the present disclosure, the display enhancement program **52** may maintain the second vergence distance constant while increasing a displayed size of the baseball as viewer Meb's eye **302** moves toward the displayed image over translation distance **324**. Accordingly and as discussed in more detail below, the display enhancement program **52** thereby enables viewer Meb **214** to view a magnified baseball while also avoiding potential viewer comfort issues by maintaining the second vergence distance **314** constant.

More particularly and as schematically illustrated in FIG. **4**, by generating a displayed enlarged baseball image **220'** at the second displayed position **312** relative to eye **302**, the display enhancement program **52** causes viewer Meb **214** to perceive the displayed enlarged baseball image **220'** as being located at a reduced perceived viewing distance **400** that is less than the predetermined threshold distance **318**, with such perception illustrated by the perceived enlarged baseball image **220"**. Accordingly, as viewer Meb **214** moves toward the baseball image and the image is progressively enlarged, he perceives himself approaching the enlarging image.

Additionally, as viewer Meb **214** may now discern details of the enlarged baseball image **220'** that may not have been discernable in the smaller baseball image **220**, the illusion of moving closer to the enlarging image is strengthened. In this manner, the display enhancement program **52** enables viewer Meb **214** to experience the enlarged baseball image **220'** as if it were actually located at the reduced perceived viewing distance **400** (as illustrated by perceived enlarged baseball image **220"**), while also avoiding potential viewer comfort issues by maintaining the second vergence distance **314** constant.

In some examples, the predetermined threshold distance **318** may be between 50.0 cm and 200.0 cm. In other examples, the predetermined threshold distance **318** may be between 75.0 cm and 175.0 cm. In other examples the predetermined threshold distance **318** may be 100 cm. It will be appreciated that the predetermined threshold distance may be established based on one or more of the display device type and display technology being utilized, properties

of the computer generated image that is displayed, viewer preferences received by the display enhancement program **52**, and environmental conditions such as ambient lighting.

In some examples and with reference to FIG. **4**, the display enhancement program **52** may determine an axis **404** that extends along a line of sight **408** of viewer Meb **214** and through a pivot point **412** of the baseball image **220**. Increasing the size of the baseball image **220** may comprise scaling the image about the axis **404**. In one example and as schematically illustrated in FIG. **4**, the pivot point **412** of the baseball image **220** may be located at a center of the 3D spherical shape of the image. In this example, as viewer Meb **214** approaches the baseball image **220**, the illusion that Meb is getting closer to the image is created by scaling the image about the axis **404**.

In one example and as the eye **302** of viewer Meb moves toward the baseball image **220** in FIGS. **3** and **4**, the display enhancement program **52** may uniformly scale the image in linear proportion to the translation distance **324** of the eye toward the image. In this manner, the display enhancement program **52** may create a smooth zooming effect as the baseball image **220** begins to increase in size after the predetermined threshold distance **318** has been reached. Advantageously, the display enhancement program **52** may thereby create for viewer Meb **214** a realistic perception of moving closer to the enlarged baseball image **220'**, while also maintaining the predetermined threshold distance **318** of the displayed image.

For example, as the eye **302** moves toward the baseball image **220**, the size of the image may be uniformly increased by a fixed percentage in linear proportion to the translation distance **324** traversed by the eye. In one example, the size of the image may be uniformly increased at a rate of 5% for each 1 cm of translation of the eye **302** toward the baseball image **220**. It will be appreciated that any suitable rate of size increase may be utilized and is within the scope of the present disclosure.

In another example, the rate of size increase of the baseball image **220** may directly correspond to the ratio between the predetermined threshold distance **318** and the distance between the eye **302** and a pivot point **412"** of the perceived enlarged baseball image **220"**. For example and with reference to FIG. **3**, when the baseball image **220** is displayed in the second current displayed position **312**, the display enhancement program **52** may display the image in a default size as shown in FIG. **3**.

With reference now to FIG. **4**, when the position of eye **302** reaches the second vergence distance **314** and the eye moves further toward the baseball image **220**, the default size of the baseball image **220** may be increased by the ratio between the predetermined threshold distance **318** and the distance between the eye **302** and the pivot point **412"** of the perceived enlarged baseball image **220"**. It will be appreciated that as the distance between the eye **302** and the pivot point **412"** of the perceived enlarged baseball image **220"** decreases, the default size of the image is linearly scaled to create the illusion of the eye moving closer to the image.

In other examples, increasing the size of the baseball image **220** may comprise proportionally scaling the image at a ratio other than 1:1 relative to translation of the eye **302** of viewer Meb **214** toward the image. In one example, the size of the baseball image **220** may be increased at a rate of 4% over the first 1 cm of translation of the eye **302** toward the baseball image **220**, 6% over the next 1 cm of translation of the eye **302**, 8% over the next 1 cm of translation, and 10% over the remaining translation distance. It will be appreciated that any suitable distance intervals and corresponding size increase percentages may be utilized and are within the scope of the present disclosure.

With reference now to FIG. **5**, in some examples the display enhancement program **52** may establish a predetermined boundary distance **500** that corresponds to a minimum perceived viewing distance between the eye **302** and the perceived enlarged baseball image **220"**. As schematically illustrated in FIG. **5**, the eye **332** may move toward the enlarged baseball image **220'** and the size of the image may be increased until the reduced perceived viewing distance **400** reaches the predetermined boundary distance **500**. Upon determining that the reduced perceived viewing distance **400** is at the predetermined boundary distance **500**, the display enhancement program **52** may display the enlarged baseball image **220"** at a maximum size.

It will also be appreciated that in some examples, due to processing limitations, data sampling intervals, and/or other constraints, the display enhancement program **52** may determine that the reduced perceived viewing distance **400** is below the predetermined boundary distance **500**. In these examples, the display enhancement program may then adjust the reduced perceived viewing distance **400** to match the predetermined boundary distance **500**.

In some examples, the predetermined boundary distance **500** may be between 0.5 cm and 4.0 cm. In other examples, the predetermined boundary distance **500** may be between 0.75 cm and 1.25 cm. In other examples, the predetermined boundary distance **500** may be 1.0 cm. It will be appreciated that the predetermined boundary distance may be established based on one or more of the display device type and display technology being utilized, properties of the computer generated image that is displayed, viewer preferences received by the display enhancement program **52**, and environmental conditions such as ambient lighting.

With reference now to FIGS. **6** and **7**, in some examples viewer Meb **214** may continue moving toward the enlarged baseball image **220'** after the reduced perceived viewing distance **400** is at the predetermined boundary distance **500**. In one example, based on the reduced perceived viewing distance **400** being at or below the predetermined boundary distance **500**, and as the eye **302** moves from an initial position **602** toward the enlarged baseball image **220'**, the display enhancement program **52** may translate the image **220'** relative to stationary real-world objects, such as the coat rack **224** and couch **228**, while maintaining the reduced perceived viewing distance at the predetermined boundary distance and maintaining the maximum size of the image.

In this example, the display enhancement program **52** may change the display mode of the enlarged baseball image **220'** from a world-lock display mode to a body-lock display mode. Accordingly and as schematically illustrated in FIGS. **6** and **7**, movement of the eye **302** over a translation distance **606** causes a corresponding translation of the enlarged baseball image **220'** by the translation distance **606**. In this manner, viewer Meb **214** perceives the perceived enlarged baseball image **220"** as being in a fixed position relative to his eye **302** and body such that movement toward the image results in a corresponding movement of the image relative to the coat rack **224** and couch **228**.

In some situations, viewer Meb **214** may move in a direction away from the enlarged baseball image **220'** such that the reduced perceived viewing distance **400** grows larger than the predetermined boundary distance **500**. In some examples, as the reduced perceived viewing distance **400** grows larger than the predetermined boundary distance **500**, the display enhancement program **52** may change the

display mode of the enlarged baseball image **220'** from the body-lock display mode to the world-lock display mode.

With reference now to FIG. **8**, one example of an HMD device **800** in the form of a pair of wearable glasses with a transparent display is provided. It will be appreciated that in other examples, the HMD device **800** may take other suitable forms in which a transparent, semi-transparent, and/or non-transparent display is supported in front of a viewer's eye or eyes. It will also be appreciated that the HMD devices shown in FIGS. **1** and **2** may take the form of the HMD device **800**, as described in more detail below, or any other suitable HMD device.

The HMD device **800** includes a display system **802** and a see-through or transparent display **804** that enables images such as holographic objects to be delivered to the eyes of a wearer of the HMD device. The transparent display **804** may be configured to visually augment an appearance of a real-world, physical environment to a wearer viewing the physical environment through the transparent display. For example, the appearance of the physical environment may be augmented by graphical content (e.g., one or more pixels each having a respective color and brightness) that is presented via the transparent display **804** to create an augmented reality environment.

The transparent display **804** may also be configured to enable a wearer of the HMD device to view a physical, real-world object in the physical environment through one or more partially transparent pixels that are displaying a virtual object representation. As shown in FIG. **8**, in one example the transparent display **804** may include image-producing elements located within lenses **806** (such as, for example, a see-through Organic Light-Emitting Diode (OLED) display). As another example, the transparent display **804** may include a light modulator on an edge of the lenses **806**. In this example, the lenses **806** may serve as a light guide for delivering light from the light modulator to the eyes of a wearer. Such a light guide may enable a wearer to perceive a 3D holographic image located within the physical environment that the wearer is viewing, while also allowing the wearer to view physical objects in the physical environment, thus creating an augmented reality environment.

The HMD device **800** may also include various sensors and related systems. For example, the HMD device **800** may include a gaze tracking system **808** that includes one or more image sensors configured to acquire image data in the form of gaze tracking data from a wearer's eyes. Provided the wearer has consented to the acquisition and use of this information, the gaze tracking system **808** may use this information to track a position and/or movement of the wearer's eyes.

In one example, the gaze tracking system **808** includes a gaze detection subsystem configured to detect a direction of gaze of each eye of a wearer. The gaze detection subsystem may be configured to determine gaze directions of each of a wearer's eyes in any suitable manner. For example, the gaze detection subsystem may comprise one or more light sources, such as infrared light sources, configured to cause a glint of light to reflect from the cornea of each eye of a wearer. One or more image sensors may then be configured to capture an image of the wearer's eyes.

Images of the glints and of the pupils as determined from image data gathered from the image sensors may be used to determine an optical axis of each eye. Using this information, the gaze tracking system **808** may then determine a direction the wearer is gazing. The gaze tracking system **808** may additionally or alternatively determine at what physical or virtual object the wearer is gazing. Such gaze tracking data may then be provided to the HMD device **800**.

It will also be understood that the gaze tracking system **808** may have any suitable number and arrangement of light sources and image sensors. For example and with reference to FIG. **8**, the gaze tracking system **808** of the HMD device **800** may utilize at least one inward facing sensor **810**.

The HMD device **800** may also include sensor systems that receive physical environment data from the physical environment. For example, the HMD device **800** may also include a head tracking system **812** that utilizes one or more pose sensors, such as pose sensors **814** on HMD device **800**, to capture head pose data and thereby enable position tracking, direction/location and orientation sensing, and/or motion detection of the wearer's head. Accordingly and as noted above, the head tracking system **812** may receive sensor data from pose sensors **814** that enable the orientation of the HMD device **800** to be estimated in three degrees of freedom or the location and orientation of the HMD device to be estimated in six degrees of freedom.

In one example, head tracking system **812** may comprise an inertial measurement unit (IMU) configured as a three-axis or three-degree of freedom position sensor system. This example position sensor system may, for example, include three gyroscopes to indicate or measure a change in orientation of the HMD device **800** within 3D space about three orthogonal axes (e.g., x, y, and z, or roll, pitch, and yaw). The orientation derived from the sensor signals of the IMU may be used to display, via the transparent display **804**, one or more virtual objects with a body-locked position in which the position of each virtual object appears to be fixed relative to the wearer of the see-through display and the position of each virtual object appears to be moveable relative to real-world objects in the physical environment.

In another example, head tracking system **812** may comprise an IMU configured as a six-axis or six-degree of freedom position sensor system. This example position sensor system may, for example, include three accelerometers and three gyroscopes to indicate or measure a change in location of the HMD device **800** along the three orthogonal axes and a change in device orientation about the three orthogonal axes.

The head tracking system **812** may also support other suitable positioning techniques, such as GPS or other global navigation systems. Further, while specific examples of position sensor systems have been described, it will be appreciated that any other suitable position sensor systems may be used. For example, head pose and/or movement data may be determined based on sensor information from any combination of sensors mounted on the wearer and/or external to the wearer including, but not limited to, any number of gyroscopes, accelerometers, inertial measurement units, GPS devices, barometers, magnetometers, cameras (e.g., visible light cameras, infrared light cameras, time-of-flight depth cameras, structured light depth cameras, etc.), communication devices (e.g., WIFI antennas/interfaces), etc.

In some examples, the HMD device **800** may also include an optical sensor system that utilizes one or more outward facing sensors, such as optical sensor **816** on HMD device **800**, to capture image data. The outward facing sensor(s) may detect movements within its field of view, such as gesture-based inputs or other movements performed by a wearer or by a person or physical object within the field of view. The outward facing sensor(s) may also capture 2D image information and depth information from the physical environment and physical objects within the environment. For example, the outward facing sensor(s) may include a

depth camera, a visible light camera, an infrared light camera, and/or a position tracking camera.

The optical sensor system may include a depth tracking system that generates depth tracking data via one or more depth cameras. In one example, each depth camera may include left and right cameras of a stereoscopic vision system. Time-resolved images from one or more of these depth cameras may be registered to each other and/or to images from another optical sensor such as a visible spectrum camera, and may be combined to yield depth-resolved video.

In other examples, a structured light depth camera may be configured to project a structured infrared illumination, and to image the illumination reflected from a scene onto which the illumination is projected. A depth map of the scene may be constructed based on spacings between adjacent features in the various regions of an imaged scene. In still other examples, a depth camera may take the form of a time-of-flight depth camera configured to project a pulsed infrared illumination onto a scene and detect the illumination reflected from the scene. For example, illumination may be provided by an infrared light source **818**. It will be appreciated that any other suitable depth camera may be used within the scope of the present disclosure.

The outward facing sensor(s) may capture images of the physical environment in which a wearer of the HMD device is situated. With respect to the HMD device **800**, in one example an augmented reality display enhancement program may include a 3D modeling system that uses such captured images to generate a virtual environment that models the physical environment surrounding the wearer of the HMD device. In some embodiments, the optical sensor **816** may cooperate with the IMU to determine the location and the orientation of the HMD device **800** in six degrees of freedom. Such location and orientation information may be used to display, via the transparent display **804**, one or more virtual objects with a world-locked position in which a position of each virtual object appears to be fixed relative to real-world objects viewable through the transparent display, and the position of each virtual object appears to be moveable relative to a wearer of the see-through display.

The HMD device **800** may also include a microphone system that includes one or more microphones, such as microphone **820**, that capture audio data. In other examples, audio may be presented to the wearer via one or more speakers, such as speaker **822** on the HMD device **800**.

The HMD device **800** may also include a controller, such as controller **824**. The controller **824** may include a logic subsystem and a storage subsystem, as discussed in more detail below with respect to FIG. **10**, that are in communication with the various sensors and systems of the HMD device **800**. In one example, the storage subsystem may include instructions that are executable by the logic subsystem to receive signal inputs from the sensors, determine a pose of the HMD device **800**, and adjust display properties for content displayed via the transparent display **804**.

FIGS. **9**A and **9**B illustrate a flow chart of a method **900** for displaying a computer generated image to a viewer via a stereoscopic display system according to an embodiment of the present disclosure. The following description of method **900** is provided with reference to the software and hardware components described above and shown in FIGS. **1-8**. It will be appreciated that method **900** may also be performed in other contexts using other suitable hardware and software components.

With reference to FIG. **9**A, at **904** the method **900** may include establishing a predetermined threshold distance from an eye of the viewer to a threshold displayed position of the computer generated image. At **908** the method **900** may include determining that a vergence distance from the eye of the viewer to a current displayed position of the computer generated image is at or below the predetermined threshold distance. At **912** the method **900** may include, based on the vergence distance being at or below the predetermined threshold distance, increasing a size of the computer generated image while maintaining the vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the computer generated image.

At **916** the predetermined threshold distance may be between 50.0 cm and 200.0 cm. At **920** the predetermined threshold distance may between 75.0 cm and 175.0 cm. At **924** the method **900** may include, as the eye of the viewer moves toward the computer generated image and the size of the computer generated image increases, determining that a perceived viewing distance is at or below a predetermined boundary distance from the eye of the viewer to the computer generated image. At **928** the method **900** may include displaying the computer generated image at a maximum size.

With reference now to FIG. **9**B, at **932** the method **900** may include, based on the perceived viewing distance being at or below the predetermined boundary distance, and as the eye of the viewer moves toward the computer generated image, translating the computer generated image relative to a stationary real-world object while maintaining the perceived viewing distance at the predetermined boundary distance and maintaining the maximum size of the computer generated image. At **936** the predetermined boundary distance may be between 0.5 cm and 4.0 cm. At **940** the predetermined boundary distance may be between 0.75 cm and 1.25 cm.

At **944** the method **900** may include increasing the size of the computer generated image by scaling the computer generated image about an axis extending along a line of sight of the viewer and through a pivot point of the computer generated image. At **948** the method **900** may include increasing the size of the computer generated image by uniformly scaling the computer generated image in linear proportion to translation of the eye of the viewer toward the computer generated image. At **952** the method **900** may include increasing the size of the computer generated image by proportionally scaling the computer generated image at a ratio other than 1:1 relative to translation of the eye of the viewer toward the computer generated image.

It will be appreciated that method **900** is provided by way of example and is not meant to be limiting. Therefore, it is to be understood that method **900** may include additional and/or alternative steps than those illustrated in FIGS. **9**A and **9**B. Further, it is to be understood that method **900** may be performed in any suitable order. Further still, it is to be understood that one or more steps may be omitted from method **900** without departing from the scope of this disclosure.

FIG. **10** schematically shows a nonlimiting example of a computing system **1000** that may perform one or more of the above described methods and processes. Computing device **10** and computing device **12** may take the form of or include one or more aspects of computing system **1000**. Computing system **1000** is shown in simplified form. It is to be understood that virtually any computer architecture may be used without departing from the scope of this disclosure. In different examples, computing system **1000** may take the form of a mainframe computer, server computer, desktop computer, tablet computer, home entertainment computer,

network computing device, tablet, notebook, smartphone, or other mobile computing device, mobile communication device, gaming device, etc.

As shown in FIG. **10**, computing system **1000** includes a logic subsystem **1004** and a storage subsystem **1008**. Computing system **1000** may optionally include a sensor subsystem **1012**, display subsystem **1016**, communication subsystem **1020**, input subsystem **1022** and/or other subsystems and components not shown in FIG. **10**. Computing system **1000** may also include computer readable media, with the computer readable media including computer readable storage media and computer readable communication media. Computing system **1000** may also optionally include other user input devices such as keyboards, mice, game controllers, and/or touch screens, for example. Further, in some embodiments the methods and processes described herein may be implemented as a computer application, computer service, computer API, computer library, and/or other computer program product in a computing system that includes one or more computers.

Logic subsystem **1004** may include one or more physical devices configured to execute one or more instructions. For example, the logic subsystem **1004** may be configured to execute one or more instructions that are part of one or more applications, services, programs, routines, libraries, objects, components, data structures, or other logical constructs. Such instructions may be implemented to perform a task, implement a data type, transform the state of one or more devices, or otherwise arrive at a desired result.

The logic subsystem **1004** may include one or more processors that are configured to execute software instructions. Additionally or alternatively, the logic subsystem may include one or more hardware or firmware logic machines configured to execute hardware or firmware instructions. Processors of the logic subsystem may be single core or multicore, and the programs executed thereon may be configured for parallel or distributed processing. The logic subsystem may optionally include individual components that are distributed throughout two or more devices, which may be remotely located and/or configured for coordinated processing. One or more aspects of the logic subsystem may be virtualized and executed by remotely accessible networked computing devices configured in a cloud computing configuration.

Storage subsystem **1008** may include one or more physical, persistent devices configured to hold data and/or instructions executable by the logic subsystem **1004** to implement the herein described methods and processes. When such methods and processes are implemented, the state of storage subsystem **1008** may be transformed (e.g., to hold different data).

Storage subsystem **1008** may include removable media and/or built-in devices. Storage subsystem **1008** may include optical memory devices (e.g., CD, DVD, HD-DVD, Blu-Ray Disc, etc.), semiconductor memory devices (e.g., RAM, EPROM, EEPROM, etc.) and/or magnetic memory devices (e.g., hard disk drive, floppy disk drive, tape drive, MRAM, etc.), among others. Storage subsystem **1008** may include devices with one or more of the following characteristics: volatile, nonvolatile, dynamic, static, read/write, read-only, random access, sequential access, location addressable, file addressable, and content addressable.

In some examples, aspects of logic subsystem **1004** and storage subsystem **1008** may be integrated into one or more common devices through which the functionally described herein may be enacted, at least in part. Such hardware-logic components may include field-programmable gate arrays (FPGAs), program- and application-specific integrated circuits (PASIC/ASICs), program- and application-specific standard products (PSSP/ASSPs), system-on-a-chip (SOC) systems, and complex programmable logic devices (CPLDs), for example.

FIG. **10** also shows an aspect of the storage subsystem **1008** in the form of removable computer readable storage media **1024**, which may be used to store data and/or instructions executable to implement the methods and processes described herein. Removable computer-readable storage media **1024** may take the form of CDs, DVDs, HD-DVDs, Blu-Ray Discs, EEPROMs, and/or floppy disks, among others.

It is to be appreciated that storage subsystem **1008** includes one or more physical, persistent devices. In contrast, in some implementations aspects of the instructions described herein may be propagated in a transitory fashion by a pure signal (e.g., an electromagnetic signal, an optical signal, etc.) that is not held by a physical device for at least a finite duration. Furthermore, data and/or other forms of information pertaining to the present disclosure may be propagated by a pure signal via computer-readable communication media.

When included, sensor subsystem **1012** may include one or more sensors configured to sense different physical phenomenon (e.g., visible light, infrared light, sound, acceleration, orientation, position, etc.) as described above. Sensor subsystem **1012** may be configured to provide sensor data to logic subsystem **1004**, for example. Such data may include gaze tracking information, image information, ambient lighting information, depth information, audio information, position information, motion information, user location information, and/or any other suitable sensor data that may be used to perform the methods and processes described above.

When included, display subsystem **1016** may be used to present a visual representation of data held by storage subsystem **1008**. As the above described methods and processes change the data held by the storage subsystem **1008**, and thus transform the state of the storage subsystem, the state of the display subsystem **1016** may likewise be transformed to visually represent changes in the underlying data. The display subsystem **1016** may include one or more display devices utilizing virtually any type of technology. Such display devices may be combined with logic subsystem **1004** and/or storage subsystem **1008** in a shared enclosure, or such display devices may be peripheral display devices.

When included, communication subsystem **1020** may be configured to communicatively couple computing system **1000** with one or more networks and/or one or more other computing devices. Communication subsystem **1020** may include wired and/or wireless communication devices compatible with one or more different communication protocols. As nonlimiting examples, the communication subsystem **1020** may be configured for communication via a wireless telephone network, a wireless local area network, a wired local area network, a wireless wide area network, a wired wide area network, etc. In some embodiments, the communication subsystem may allow computing system **1000** to send and/or receive messages to and/or from other devices via a network such as the Internet.

When included, input subsystem **1022** may comprise or interface with one or more sensors or user-input devices such as a game controller, gesture input detection device, voice recognizer, inertial measurement unit, keyboard, mouse, or touch screen. In some embodiments, the input

subsystem **1022** may comprise or interface with selected natural user input (NUI) componentry. Such componentry may be integrated or peripheral, and the transduction and/or processing of input actions may be handled on- or off-board. Example NUI componentry may include a microphone for speech and/or voice recognition; an infrared, color, stereoscopic, and/or depth camera for machine vision and/or gesture recognition; a head tracker, eye tracker, accelerometer, and/or gyroscope for motion detection and/or intent recognition; as well as electric-field sensing componentry for assessing brain activity.

The term "program" may be used to describe an aspect of computing device **10** and computing device **12** that is implemented to perform one or more particular functions. In some cases, such a program may be instantiated via logic subsystem **1004** executing instructions held by storage subsystem **1008**. It is to be understood that different programs may be instantiated from the same application, service, code block, object, library, routine, API, function, etc. Likewise, the same program may be instantiated by different applications, services, code blocks, objects, routines, APIs, functions, etc. The term "program" is meant to encompass individual or groups of executable files, data files, libraries, drivers, scripts, database records, etc.

It will be understood that the configurations and/or approaches described herein are exemplary in nature, and that these specific embodiments or examples are not to be considered in a limiting sense, because numerous variations are possible. The specific routines or methods described herein may represent one or more of any number of processing strategies. As such, various acts illustrated and/or described may be performed in the sequence illustrated and/or described, in other sequences, in parallel, or omitted. Likewise, the order of the above-described processes may be changed.

The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

The invention claimed is:

1. A method for displaying a computer generated image to a viewer via a stereoscopic display system, the method comprising:

establishing a predetermined threshold distance from an eye of the viewer to a viewer perceived threshold displayed position of the computer generated image;

determining that a vergence distance from the eye of the viewer to a viewer perceived current displayed position of the computer generated image is at or below the predetermined threshold distance, wherein the vergence distance is the distance between the eye of the viewer and a predetermined location associated with the image; and

based on the vergence distance being at or below the predetermined threshold distance, increasing a size of the computer generated image while maintaining the vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image.

2. The method of claim **1**, wherein the predetermined threshold distance is between 50.0 cm and 200.0 cm.

3. The method of claim **1**, wherein the predetermined threshold distance is between 75.0 cm and 175.0 cm.

4. The method of claim **1**, further comprising:

as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image and the size of the computer generated image increases, determining that a perceived viewing distance is at or below a predetermined boundary distance from the eye of the viewer to the computer generated image;

displaying the computer generated image at a maximum size; and

based on the perceived viewing distance being at or below the predetermined boundary distance, and as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image, translating a viewer perceived position of the computer generated image relative to a stationary real-world object while maintaining the perceived viewing distance at the predetermined boundary distance and maintaining the maximum size of the computer generated image.

5. The method of claim **4**, wherein the predetermined boundary distance is between 0.5 cm and 4.0 cm.

6. The method of claim **4**, wherein the predetermined boundary distance is between 0.75 cm and 1.25 cm.

7. The method of claim **1**, wherein increasing the size of the computer generated image further comprises scaling the computer generated image about an axis extending along a line of sight of the viewer and through a pivot point of the computer generated image.

8. The method of claim **1**, wherein increasing the size of the computer generated image further comprises uniformly scaling the computer generated image in linear proportion to translation of the eye of the viewer toward the computer generated image.

9. The method of claim **1**, wherein increasing the size of the computer generated image further comprises proportionally scaling the computer generated image at a ratio other than 1:1 relative to translation of the eye of the viewer toward the computer generated image.

10. A head-mounted display device configured to display a computer generated image to a viewer via a stereoscopic display system, the head-mounted display device comprising:

a computing device; and

a display enhancement program executed by a processor of the computing device, the display enhancement program configured to:

establish a predetermined threshold distance from an eye of the viewer to a viewer perceived threshold displayed position of the computer generated image;

determine that a vergence distance from the eye of the viewer to a viewer perceived current displayed position of the computer generated image is at or below the predetermined threshold distance, wherein the vergence distance is the distance between the eye of the viewer and a predetermined location associated with the image; and

based on the vergence distance being at or below the predetermined threshold distance, increasing a size of the computer generated image while maintaining the current vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image.

11. The head-mounted display device of claim **10**, wherein the predetermined threshold distance is between 50.0 cm and 200.0 cm.

12. The head-mounted display device of claim 10, wherein the predetermined threshold distance is between 75.0 cm and 175.0 cm.

13. The head-mounted display device of claim 10, wherein the display enhancement program is further configured to:

as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image and the size of the computer generated image increases, determine that a perceived viewing distance is at or below a predetermined boundary distance from the eye of the viewer to the computer generated image;

display the computer generated image at a maximum size; and

based on the perceived viewing distance being at or below the predetermined boundary distance, and as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image, translate a viewer perceived position of the computer generated image relative to a stationary real-world object while maintaining the perceived viewing distance at the predetermined boundary distance and maintaining the maximum size of the computer generated image.

14. The head-mounted display device of claim 13, wherein the predetermined boundary distance is between 0.5 cm and 4.0 cm.

15. The head-mounted display device of claim 13, wherein the predetermined boundary distance is between 0.75 cm and 1.25 cm.

16. The head-mounted display device of claim 10, wherein increasing the size of the computer generated image further comprises scaling the computer generated image about an axis extending along a line of sight of the viewer and through a pivot point of the computer generated image.

17. The head-mounted display device of claim 10, wherein increasing the size of the computer generated image further comprises uniformly scaling the computer generated image in linear proportion to translation of the eye of the viewer toward the computer generated image.

18. The head-mounted display device of claim 10, wherein increasing the size of the computer generated image further comprises proportionally scaling the computer generated image at a ratio other than 1:1 relative to translation of the eye of the viewer toward the computer generated image.

19. The head-mounted display device of claim 10, further comprising a plurality of sensors selected from the group consisting of a depth sensor, an optical sensor, a gyroscope, and an accelerometer.

20. A method for displaying a computer generated image to a viewer via a stereoscopic display system, the method comprising:

establishing a predetermined threshold distance from an eye of the viewer to a viewer perceived threshold displayed position of the computer generated image;

determining that a vergence distance from the eye of the viewer to a viewer perceived current displayed position of the computer generated image is at or below the predetermined threshold distance, wherein the vergence distance is the distance between the eye of the viewer and a predetermined location associated with the image;

based on the vergence distance being at or below the predetermined threshold distance, increasing a size of the computer generated image while maintaining the vergence distance at the predetermined threshold distance as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image;

determining that a perceived viewing distance is at or below a predetermined boundary distance from the eye of the viewer to the computer generated image;

displaying the computer generated image at a maximum size; and

based on the perceived viewing distance being at or below the predetermined boundary distance, and as the eye of the viewer moves toward the viewer perceived threshold displayed position of the computer generated image, translating a viewer perceived position of the computer generated image relative to a stationary real-world object while maintaining the perceived viewing distance at the predetermined boundary distance and maintaining the maximum size of the computer generated image.

* * * * *